(19) Japan Patent Office
(12) Patent application publication (A)
(11) Publication number Laid open No. 2003-59909 (P2003-59909A)
(43) Publication date February 28, H15 (2003, 2, 28)

(51) Int. Cl.[7]	Identification symbol	FI	Theme code (reference)
H01L 21/3065		C23C 16/515	4K030
C23C 16/515		H05H 1/24	5F004
H05H 1/24		H01L 21/302	C

Examination: not requested, the number of claims: 7 OL (total 6 pages)

(21) Application number 2001-248042 (P2001-248042)
(22) Application date August 17, H13 (2001, 8, 17)
(71) Applicant 000002174
Sekisui Chemical Co., LTD.
2-4-4 Nishitennma, Kita-ku, Osaka, Osaka
(72) Inventor Satoshi Mayumi
c/o Sekisui Chemical Co., LTD.
2-1 Hyakuyama, Shimamoto-co, Mishima-gun, Osaka
F term (reference)
4K030 FA01 KA30
5F004 BA06 BB29 BC06 BD04 CA03
DA01 DA23 DB03

(54) [Title of invention]

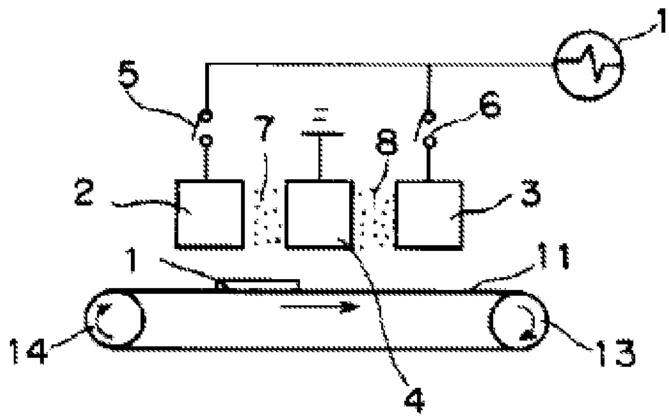
Discharge plasma treatment apparatus and treatment method using the same

(57) [Abstract]
[Objective]

To provide a discharge plasma treatment apparatus which has a plurality of discharge spaces but is able to avoid duplicate of equipment and to independently form discharge plasma in the plurality of discharge spaces.

[Means for solving problem]

A discharge plasma treatment apparatus in which two or more discharge spaces are provided by using three or more electrodes, at least one surface of the electrodes opposing to each other is covered by a solid dielectric, and in which electric field is applied between the electrodes to generate discharge plasma, where the apparatus is characterized in that the plurality of electrodes to which voltage is applied are connected to one power source.



[Scope of claims]

[Claim 1]

A discharge plasma treatment apparatus to generate discharge plasma by applying electric field between electrodes where two or more discharge spaces are formed by using three or more electrodes and at least one of surfaces of the plurality of electrodes opposing to each other is covered by a solid dielectric,

wherein the discharge plasma apparatus is characterized in that the plurality of electrodes to which voltage is applied are connected to one power source.

[Claim 2]

The discharge plasma treatment apparatus according to claim 1,

wherein the plurality of electrodes to which voltage is applied are connected to one power source, and

wherein on/off control is individually provided for the plurality of electrodes to which voltage is applied.

[Claim 3]

The discharge plasma treatment apparatus according to claim 1 or 2,

wherein the plurality of electrodes to which voltage is applied are connected to one power source, and

wherein plasma of a treatment gas excited between the plurality of electrodes, to which voltage is applied and which are individually provided with an on/off control, and a ground electrode is blown to a substrate to be treated which is placed outside the discharge spaces.

[Claim 4]

The discharge plasma treatment apparatus according to claim 1 or 2,

wherein the plurality of electrodes to which voltage is applied are connected to one power source,

wherein a substrate to be treated is provided between the plurality of electrodes, to which voltage is applied and which are individually provided with an on/off control, and a ground electrode, and

wherein a surface of the substrate is treated by a treatment gas excited between the plurality of electrodes.

[Claim 5]

The discharge plasma treatment apparatus according to claim 1 or 2,

wherein the plurality of electrodes to which voltage is applied are connected to one power source,

wherein a substrate to be treated is provided between the plurality of electrodes, to which voltage is applied and which are individually provided with an on/off control, and a ground electrode,

wherein a surface of the substrate is treated by plasma of a treatment gas excited between the plurality of electrodes, and

wherein both surfaces of the substrate over the ground electrode are simultaneously treated with the discharge plasma.

[Claim 6]

The discharge plasma treatment apparatus according to any of claims 1 to 5,

wherein the electric field is a pulse electric field with a voltage rise time equal to or less than 10 μs and an intensity of 10 to 1000 kV/cm.

[Claim 7]

A discharge plasma treatment method to treat a substrate to be treated using the discharge plasma treatment apparatus according to any of claims 1 to 6.

[Detailed description of the invention]

[0001]

[Technical field to which the invention belongs]

The invention relates to a discharge plasma treatment apparatus, especially a discharge plasma treatment apparatus having a plurality of electrodes in which a power source for the electrodes to which voltage is applied is shared, by which duplicate of equipment can be avoided and the plasma discharge can be independently controlled for any of the pairs of the electrodes.

[0002]

[Prior art]

A method has been conventionally put to practical use to treat a surface of a member to be treated or to form a thin film on the member by generating a glow discharge plasma under a reduced pressure. However, these kinds of treatment in

reduced pressure require a vacuum chamber, a vacuum exhausting apparatus, and the like, which increases the cost of the surface treatment apparatus, and thus, such a treatment apparatus has been hardly used for treating a large-area substrate and the like. Hence, a method has been proposed in which discharge plasma is generated under a pressure close to a normal atmospheric pressure.

[0003]

As shown in laid open H6-2149 and laid open H7-85997, as a general plasma treating method under an atmospheric pressure, adopted is a method comprising:

providing a member to be treated between parallel plate type electrodes in a treatment chamber and covered by a solid dielectric or the like;

introducing a treatment gas to the treatment chamber; and

treating the member by the plasma generated by applying a voltage between the electrodes.

According to these methods, the member is treated in one discharge space. Thus, it is impossible to flexibly respond to a variety of treatment requirements.

[0004]

Additionally, a remote type plasma treatment apparatus having a plasma gas outlet at an end has been developed which facilitates to perform a plasma treatment on a specific part of the member to be treated and is able to continuously treat the member to be treated. For example, laid open H11-251304 and H11-260597 disclose a plasma treatment apparatus which includes:

a tube-shaped reactive tube having an external electrode and an internal electrode in the inside thereof; and

a cooling means for both of the external and the internal electrodes,

wherein a glow discharge is generated in the reactive tube and a plasma jet is blown and provided to the member to be treated from the reactive tube.

However, in the above-mentioned apparatus, since plasma which is generated by alternating current is utilized, a cooling process is indispensable, which reduces the efficiency. Additionally, streamer discharge readily occurs. Furthermore, the discharge space for the plasma generation is a simple one-chamber type. Therefore, it cannot be sufficiently applied to complicated treatment such as the formation of a composite oxide thin layer by a CVD method, the formation of a stacked thin layer, an etching treatment, an ashing treatment, and so on in the manufacturing process of a semiconductor element.

[0005]

[Problems to be solved by the invention]

The invention is based on the above-mentioned problems and has a purpose of providing a discharge plasma treatment apparatus which has a plurality of discharge spaces and is able to avoid duplicate of equipment, and simultaneously able to independently generate discharge plasma in a plurality of discharge spaces.

[0006]

[Means for solving problems]

The inventor has intensively conducted research for solving the above-mentioned problems and found that the plasma discharge can be independently controlled between the electrodes and the duplicate of equipment can be avoided by providing a discharge plasma treatment apparatus having three or more electrode plates to provide two or more discharge spaces and by sharing the connection of the plurality of electrodes to which voltage is applied to a power source and further by preferably providing a switch to a voltage application cable.

[0007]

Namely, the first invention is a discharge plasma treatment apparatus which is arranged to generate discharge plasma, in which:

two or more discharge spaces are provided by using three or more electrodes;

at least one of surfaces of the electrodes opposing to each other is covered by a solid dielectric; and

electric field is applied between the electrodes to generate discharge plasma,

wherein the plurality of electrodes to which voltage is applied are connected to one power source.

[0008]

The second invention is the discharge plasma treatment apparatus according to the first invention, wherein the plurality of electrodes to which voltage is applied are connected to the one power source, and wherein an on/off is controlled for each of the plurality of electrodes to which voltage is applied.

[0009]

The third invention is the discharge plasma treatment apparatus according to the first or second invention, wherein the plurality of electrodes to which voltage is applied are connected to one power source, and wherein the plasma of the treatment gas excited between the plurality of electrodes, to which voltage is applied and the on/off control is independently provided, and the ground electrode is blown onto the substrate to be treated which is placed outside the discharge spaces.

[0010]

The fourth invention is the discharge plasma treatment apparatus according to

the first or second invention, wherein the plurality of electrodes to which voltage is applied are connected to the one power source, wherein the substrate to be treated is provided between the plurality of electrodes, to which voltage is applied and the on/off control is independently provided, and the ground electrode, and wherein a surface of the substrate to be treated is treated by the treatment gas excited between the plurality of electrodes.

[0011]

The fifth invention is the discharge plasma treatment apparatus according to the first or second invention, wherein the plurality of electrodes to which voltage is applied are connected to the one power source, wherein the substrate to be treated is provided between the plurality of electrodes, to which voltage is applied and the on/off control is independently provided, and the ground electrode, and wherein the substrate to be treated is treated by the plasma of the treatment gas excited between the plurality of electrodes, and wherein both surfaces of the substrate located over the ground electrode are simultaneously treated with the discharge plasma.

[0012]

The sixth invention is the discharge plasma treatment apparatus according to any of the first to fifth inventions, wherein the electric field is a pulse electric field with a voltage rise time of 10 μs or less and an intensity of 10 to 1000 kV/cm.

[0013]

Moreover, the seventh invention is a discharge plasma treatment method to treat the substrate to be treated using the discharge plasma treatment apparatus according to any of the first to sixth inventions.

[0014]

[Embodiment]

The discharge plasma treatment apparatus of the invention uses three or more electrodes where at least one of the surfaces of the electrodes opposing to each other is covered by a solid dielectric. Two or more discharge spaces are provided by the electrodes opposing to each other. The treatment gas is blown to the discharge spaces. When the electric field is applied between the plurality of electrodes to which voltage is applied, the power source which is connected to the plurality of electrodes to which voltage is applied is shared to avoid the plurality of electrodes being individually connected to power sources, by which duplicate of equipment can be avoided. Additionally, the treatment gas is blown to a plurality of discharge spaces under a pressure close to an atmospheric pressure, and the electric field, preferably a pulse electric field, is applied for each electrode through a switch provided on a voltage

application cable so that discharge plasma to be generated can be controlled in each discharge space, by which the substrate to be treated can be treated for a variety of usage. The invention is explained below in detail.

[0015]

An example of the apparatus of the invention is explained by Figures. Fig. 1 is a schematic drawing explaining an apparatus in which three electrodes are utilized, a discharge space is formed between two of the electrodes, and the substrate to be treated which is located outside the discharge space is treated by discharge plasma generated in the two discharge spaces. The electrodes 2 and 3 to which voltage is applied are connected to the power source 1 through the voltage application cables, and switches 5 and 6 are provided to the respective cables. Note that, although no illustration is provided in the Figure, the surfaces of the electrodes which are opposing to each other are coated by a solid dielectric. The discharge space 7 is formed between the ground electrode 4 and the electrode 2, and the discharge space 8 is formed between the ground electrode 4 and the electrode 3. A substrate to be treated 10 is placed on a transport belt 11 which is moved by rolls 12 and 13 and treated by the discharge plasma generated in the discharge spaces 7 and 8. The discharge conditions of the discharge spaces 7 and 8 can be independently controlled by controlling the on/off of the switches 5 and 6. In the case of the treatment using initially formed plasma, the treatment is carried out by turning the switch 5 on and turning the switch 6 off, and vice versa, and further treatment can be performed by turning both switches on. Furthermore, different treatment gases can be blown to the discharge spaces, by which a special treatment can be carried out.

[0016]

Fig. 2 is a schematic drawing explaining an apparatus in which three electrodes are used, two discharge spaces are formed, the substrate to be treated is moved in the discharge spaces and treated with the discharge plasma generated in the discharge spaces. The electrodes 2 and 3 to which voltage is applied are connected to the power source 1 through the voltage application cables, and switches 5 and 6 are provided to the respective cables. The ground electrode 4 also functions as the transport belt which is moved by the rolls 12 and 13. The discharge space 7 is formed between the ground electrode 4 and the electrode 2, and the discharge space 8 is formed between the ground electrode 4 and the electrode 3. A substrate 10 to be treated is placed on the ground electrode 4 which simultaneously functions as the transport belt moved by the rolls 12 and 13 and treated in the discharge plasma generated in the discharge spaces 7 and 8. Although no illustration is provided, the surfaces of the electrodes which are

opposing to each other are covered with a solid dielectric. The discharge conditions of the discharge spaces 7 and 8 can be independently controlled by controlling the on/off of the switches 5 and 6. In the case of the treatment using initially formed plasma, the treatment is carried out by turning the switch 5 on and turning the switch 6 off, and vice versa, and further treatment can be performed by turning both switches on. Furthermore, different treatment gases can be blown to the discharge spaces, by which a special treatment can be carried out.

[0017]

Fig. 3 is a schematic drawing explaining an apparatus in which three electrodes are used, two discharge spaces are formed, the substrate to be treated is moved in the discharge spaces, and the top and bottom surfaces of the substrate are treated with the discharge plasma generated in the discharge spaces. The electrodes 2 and 3 to which voltage is applied are connected to the power source 1 through the voltage application cables, and switches 5 and 6 are provided to the respective cables. The ground electrode 4 also functions as a transport belt which is moved by the rolls 12 and 13. The discharge space 7 is formed between the ground electrode 4 and the electrode 2. The ground electrode 4' also functions as a transport belt which is moved by the rolls 12' and 13', and the discharge space 7' is formed between the ground electrode 4' and the electrode 2. Furthermore, a discharge space 8 is formed between the ground electrode 4 and the electrode 3 and between the ground electrode 4' and the electrode 3. A substrate 10 to be treated is placed on the ground electrode 4 which simultaneously functions as the transport belt moved by the rolls 12 and 13, and the top surface of the substrate 10 is treated in the discharge plasma generated in the discharge spaces 7 and 7'. Simultaneously, the bottom surface of the substrate 10 is treated in the discharge spaces 8 between the ground electrode 4 and the electrode 3 and between the ground electrode 4' and the electrode 3. Although no illustration is provided, the surfaces of the electrodes which are opposing to each other are covered with a solid dielectric. In this case, the desired position of the top and bottom surfaces of the substrate can be also treated by turning the switch 5 or 6 on/off as appropriate. Furthermore, different treatment gases can be blown to the discharge spaces, by which a special treatment can be carried out.

[0018]

By sharing the power source by the electrodes to which voltage is applied, duplicate of equipment can be avoided, enabling the cost reduction and the downsizing of equipment. Moreover, the independent control by providing the on/off switch to each of the voltage application cables can facilitate the change of the treatment in

accordance with the change of the substrate. Additionally, the modification of the arrangement of the two kinds of ground electrodes which simultaneously function as the transport belts provides an advantage that both top and bottom surfaces of the substrate can be simultaneously treated.

[0019]

As the materials for the above-mentioned opposing electrodes, a material formed of a metal element such as copper and aluminum, an alloy such as stainless steel and brass, an intermetallic compound, and the like can be given.

[0020]

A structure is preferred that the distance between the above-mentioned opposing electrodes are substantially constant in order to avoid the formation of an arc discharge promoted by the concentration of electric field. As a structure of the electrode which satisfies such conditions, for example, a parallel plate type, a circular cylinder-plate opposing type, a sphere-plate opposing type, a hyperbolic-plate opposing type, a coaxial cylinder structure type, and the like can be given. Since three or more of electrodes are used in the invention, the parallel plate type is preferred.

[0021]

The solid dielectric which covers the above-mentioned electrodes is provided to one or both of the surfaces of electrodes which are opposing to each other. In this case, the solid dielectric is provided so as to closely attach to and fully cover the surface of the electrodes. When a portion which is not covered by the solid dielectric is directly opposing to the opposing electrode, an arc discharge is readily formed from that portion.

[0022]

The shape of the above-mentioned solid dielectric may be a sheet shape or a film shape. It is preferred that the thickness thereof is 0.01 to 4 mm. If the thickness is too large, high voltage is required to form discharge plasma, and if the thickness is too small, breakdown readily occurs in applying voltage to lead to the formation of an arc discharge.

[0023]

As the material for the above-mentioned solid dielectric, for example, a plastic such as polytetrafluoroethylene and poly(ethylene telephthalate), glass, a metal oxide such as silicon dioxide, aluminum oxide, zirconium dioxide, and titanium dioxide, a double oxide such as barium titanate, and the stacked structure thereof can be given.

[0024]

Furthermore, the above-mentioned solid dielectric is preferred to have a

relative dielectric constant of 2 or more (at 25 °C). A specific example of a dielectric having a relative dielectric constant of 2 or more is polytetrafluoroethylene, glass, a metal oxide film, and the like. In order to stably generate discharge plasma with high density, it is preferred to use a solid dielectric having a relative dielectric constant of 10 or more. The upper limit of the relative dielectric constant is not particularly provided in the invention. A material having a relative dielectric constant of around 18,500 is known. As a solid dielectric with a relative dielectric constant of 10 or more, a metal oxide film in which 5 to 50 wt% of titanium oxide and 50 to 95 wt% of aluminum oxide are mixed or a metal oxide film having zirconium oxide is preferred, for example.

[0025]

The distance between the above-mentioned electrodes is determined as appropriate by the thickness of the solid dielectric, magnitude of the applied voltage, and purpose of using plasma, and the like. It is preferred to be 0.1 to 50 mm, and more preferred to be 5 mm or less. If the thickness exceeds 50 mm, it is difficult to form uniform discharge plasma.

[0026]

An electric field is applied between the above-mentioned electrodes to generate plasma. It is preferred to apply a pulse electric field, and more preferred to apply an electric field having a rise time and/or fall time of 10 μs or less. If the rise time and/or fall time exceeds 10 μs, the discharge state is readily transferred to an arc state and becomes unstable, which makes it difficult to keep a high density plasma state by the pulse electric field. The decrease in rise time and fall time results in increase in efficiency of the ionization of the gases in the generation of plasma. However, it is practically difficult to obtain a pulse electric field having a rise time of less than 40 ns. 50 ns to 5μs is more preferred. Note that the rise time represents a time in which the voltage (absolute value) is continuously increased, and the fall time represents a time in which the voltage (absolute value) is continuously decreased.

[0027]

It is preferred that the intensity of the above-mentioned pulse electric field is controlled to be 10 to 1000 kV/cm. If the intensity of the electric field is less than 10 kV/cm, the treatment requires too long time, and if the intensity exceeds 1000 kV/cm, arc discharge readily occurs.

[0028]

It is preferred that the frequency of the above-mentioned pulse electric field is 0.5 kHz or more. If the frequency is less than 0.5 kHz, very long time is required to achieve the treatment since the density of the plasma is low. The upper limit is not

particularly provided. A high frequency band such as commonly used 13.56 MHz and experimentally used 500 MHz can be applied. Considering the facility in balancing with a load and in usage, a frequency of 500 kHz or less is preferred. Application of such a pulse electric field can significantly improve the rate of the treatment.

[0029]

Additionally, the continuation time of one pulse of the above-mentioned pulse electric field is preferably 200 μs or less, and more preferably 3 to 200 μs. If the time exceeds 200 μs, transformation to the arc discharge readily occurs. Here, the continuation time of one pulse is the on-state time of the continuation of one pulse of the pulse electric field consisting of on and off states as exemplified in Fig. 9.

[0030]

In the above-mentioned treatment apparatus, the treatment pressure is not particularly limited; however, a pressure close to an atmospheric pressure is preferred. The pressure close to an atmospheric pressure represents a pressure of 1.333×10^4 to 10.664×10^4 Pa. In particular, a pressure range of 9.331×10^4 to 10.397×10^4 Pa is preferred since the control of the pressure is easily carried out and the apparatus can be simplified.

[0031]

Under a pressure close to an atmospheric pressure, only the method of the invention in which the pulse state electric field is applied is able to stably generate discharge plasma in an atmosphere of helium and the like which does not include a long-time component in transforming from the plasma discharge state to the arc discharge sate.

[0032]

Note that, according to the method of the invention, it is possible to generate glow discharge plasma regardless of the kind of gas which is present in the plasma formation space. It is conventionally required to perform the treatment in a sealed vessel not only for the known plasma treatment under a low pressure condition but also for the plasma treatment under an atmospheric pressure of a specified gas. However, according to the glow discharge plasma treatment of the invention, it is possible to perform the treatment in the opened system or in a roughly sealed system in which gas is only prevented from freely being leaked.

[0033]

As a substrate which can be treated by the invention, a plastic such as polyethylene, polypropyrene, polystyrene, polycarbonate, poly(ethylene telephthalate), polytetrafluoroethylene, and an acrylic resin, glass, ceramic, a metal, and the like can be

given. The shape of the substrate can be exemplified by a plate shape, a film shape, and the like, but is not particularly limited thereto. According to the surface treatment method of the invention, it is possible to readily perform the treatment on a substrate with a variety of shapes.

[0034]

As a treatment gas used in the invention, no limitation is provided as long as a gas which can generate plasma by applying an electric field, preferably a pulse electric field, is employed, and a variety of gases can be used depending on the purpose of the treatment.

[0035]

The use of a compound gas containing fluorine such as CF_4, C_2F_6, $CClF_3$, and SF_6 as the above-mentioned gas for the treatment allows the formation of a hydrophobic surface.

[0036]

Alternatively, the use of a compound including an oxygen element such as O_2, O_3, water, and air, a compound including a nitrogen element such as N_2 and NH_3, or a compound containing a sulfur element such as SO_2 and SO_3 allows the formation of a hydrophilic functional group such as a carbonyl group, a hydroxyl group, and an amino group on the surface of the substrate, which increases surface energy thereof to result in a hydrophilic surface. Additionally, it is possible to deposit a hydrophilic polymeric film by using a polymerizable monomer having a hydrophilic group such as acrylic acid and methacrylic acid.

[0037]

Additionally, it is possible to use a treatment gas such as a metal hydride, a metal-halogen compound, and a metal alkolato of a metal such as Si, Ti, and Sn in order to form a metal oxide thin layer such as SiO_2, TiO_2, and SnO_2, which allows an electric function or an optical function to be provided to the surface of the substrate. It is also possible to perform an etching treatment and dicing treatment by using a halogenated gas, to perform a resist treatment and remove of an organic contaminant by using an oxygen-containing gas, and to perform a surface cleaning and a surface modification by using an inert gas such as argon and nitrogen.

[0038]

The method of the present invention can be applied to a multi-chamber apparatus. Specifically, plasma apparatuses having different gases or treatment conditions are arranged in the direction of the transport of the substrate, and the film formation process, etching, and cleaning treatment, and the like are performed in the

corresponding apparatus, by which these processes can be conducted continuously and simultaneously. In this multi-chamber apparatus, it is possible to combine the plasma treatment method of the invention with another method. It is also possible to use a multistage apparatus having a plurality of pairs of electrodes in order to increase the rate of the treatment and to introduce a different gas to each of the stage in order to form a stacked film.

[0039]

From the economical and safety viewpoint, it is preferred to conduct the treatment in the atmosphere where the above-mentioned gas is diluted by a diluting gas shown below rather than in the atmosphere where the treatment gas is singly used. As the diluting gas, a noble gas such as helium, neon, argon, and xenon, nitrogen, and the like are given. These gases may be used singly, and the mixture of two or more of these gases may be used. It is preferred that, when the noble gas is used, the proportion of the treatment gas is in the range of 0.001 vol% to 10 vol%.

[0040]

Note that, as mentioned above, it is advantage to use a compound having more electrons as a gas because plasma density can be increased and treatment can be performed rapidly. Thus, the most preferred selection is an atmosphere containing argon and/or nitrogen as the diluting gas when availability, cost performance, and the treatment rate are taken into consideration.

[0040]

In the atmospheric pressure discharge using the pulse electric field of the invention, the discharge is not influenced by the kind of the gas, and the discharge can be directly formed between the electrodes under an atmospheric pressure. Thus, it is possible to provide an atmospheric pressure plasma apparatus in which the structure of electrodes and process for the discharging can be significantly simplified, to simplify the treatment method, and to achieve a very high-rate treatment. Moreover, parameters which relate to the treatment can be adjusted by a parameter such as the pulse frequency, the voltage, the distance between the electrodes, and the like.

[0042]

[Example]

The invention is specifically explained by using examples below; however, the invention is not limited to these examples.

[0043]

Example 1

A SiO_2 film over a substrate film was etched with a treatment gas of CF_4 to

which Ar ($CF_4/Ar = 40/60$) was added by using an apparatus of Fig. 1. A comb-shaped electrode formed of alumina with a distance between the electrodes of 8 μm was used as the electrodes 2 and 3 to which voltage is applied, and a comb-shaped electrode formed of alumina opposing to the electrodes to which voltage is applied was used as a ground electrode under the following conditions: the distance between the electrodes was 2 mm; the distance between the substrate and the electrodes was 1 mm, and the transport rate of the substrate was 50 mm/min. A groove with a depth whose etching rate is 5 nm/min was obtained by the discharge treatment gas from the discharge space 7, and a groove with a depth whose etching rate is 20 nm/min was obtained by the discharge treatment gas from the discharge space 8. Thus, a groove of 200 angstrom was obtained as a whole. Note that the applied voltage was 16 kVpp, and the frequency was 10 kHz. The obtained substrate film was used as an SWA filter (surface wave filter) and adoptable to a mobile phone.

[0044]

Example 2

A desmear treatment was performed on a multilayer wiring substrate using an apparatus shown in Fig. 3. A 100×500 mm electrode formed of SUS, a 100×500 mm electrode formed of SUS, a transport belt formed of SUS, and a transport belt formed of SUS were used as an electrode 2 to which voltage is applied, an electrode 3 to which voltage is applied, a ground electrode 4, and a ground electrode 4', respectively, under the following conditions: the distance between the ground electrodes 4 and 4' and the electrodes 2 and 3 to which voltage is applied was 54 mm, and the distance between the ground electrodes 4 and 4' was 150 mm. The treatment was carried out by applying a pulse electric field of 20 kVpp and 10 kHz under a flow of a dried air in the discharge space while a copper stacked plate having a penetration hole of 100 μmϕ was transferred in the transfer rate of 50 mm/min. The results were observed by a microscopy to confirm that the desmear treatment was performed well.

[0045]

[Effect of invention]

According to the discharge plasma treatment apparatus of the invention, it is possible to avoid duplicate of equipment while having a plurality of discharge spaces, and the apparatus can independently generate discharge plasma in a plurality of discharge spaces. Therefore, reduction of the cost and the downsizing of equipment are achieved, and the treatment condition can be readily changed for an individual substrate. Moreover, it has an advantage that a discharge space can be formed by a small number of electrodes, which can be achieved by using both surfaces of the

electrode as a discharge surface. It is also possible to use a hazardous gas safely and to precisely adjust the film formation conditions. Additionally, different gases can be independently excited and decomposed in two or more discharge spaces, and hence, complicated treatments can be performed simultaneously.

[0046]

[Brief explanation of drawings]

Fig. 1 A drawing explaining an example of an apparatus to treat a substrate according to the invention.

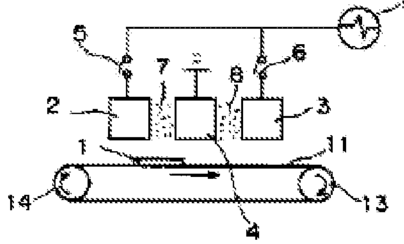
Fig. 2 A drawing explaining an example of an apparatus to treat a substrate according to the invention.

Fig. 3 A drawing explaining an example of an apparatus to treat a substrate according to the invention.

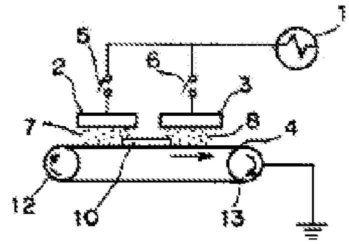
[Reference number]

1. Power source
2, 3. Electrode to which voltage is applied
4, 4' Ground electrode
5, 6 Switch
7, 7', 8 Discharge space
10 Substrate to be treated
11. Transport belt
12, 12', 13, 13' Transport roll

【図1】



【図2】



【図3】